dard 10-mm sections. "Thin-section" images have proved useful in a number of acute and chronic diseases of the lung and are a standard feature of all CT scanners.

The evaluation of acute nodular disease is aided by high-resolution CT when a surrounding halo of ground-glass attenuation is seen. Although the "CT halo sign" may be seen with any hemorrhagic nodule, whether infectious or neoplastic, in patients with neutropenia, this finding strongly suggests the diagnosis of invasive aspergillosis. In many acute lung diseases such as *Pneumocystis carinii* pneumonia and acute radiation pneumonitis, high-resolution CT can demonstrate early parenchymal abnormalities when other techniques give negative or equivocal results. False-positive results due to dependent atelectasis are reduced by the combination of prone and supine scanning.

In patients with chronic diffuse lung disease, a firm diagnosis is rarely provided by conventional radiography, and 10% to 15% may have a normal chest x-ray film. In several studies, high-resolution CT has demonstrated both a higher diagnostic sensitivity and specificity. Occasionally high-resolution CT findings may be so characteristic of a specific disease that therapy can be initiated without biopsy confirmation of the diagnosis. For example, reticular opacities in a predominantly subpleural and basilar distribution in a patient older than 50 years presenting with subacute dyspnea and restrictive functioning are generally sufficient for a diagnosis of usual interstitial pneumonia. The presence of nodular (interlobular) septal thickening with polygon formation is considered nearly pathognomonic of the lymphangitic spread of tumor.

In patients with chronic diffuse lung disease, areas of ground-glass opacification suggest active, possibly treatable disease and are the appropriate targets for biopsy. By providing a rough map and index of disease activity, that is, alveolitis versus fibrosis, high-resolution CT helps guide therapeutic decisions and limits biopsy site sampling errors. High-resolution CT also aids in choosing the best biopsy technique. Although transbronchial biopsy is appealing as a less-invasive technique than thoracoscopic or open-lung biopsy, it has a high yield only in diseases involving the lung tissue adjacent to bronchovascular bundles. The best examples are sarcoidosis and lymphangitic carcinomatosis. Most other chronic diffuse lung diseases usually require a surgical biopsy for definitive diagnosis.

Mild emphysema may be difficult to detect radiographically, even when suggested by the results of pulmonary function tests. High-resolution CT may show subtle emphysematous changes or bullous disease, thus explaining the pulmonary function abnormalities and directing appropriate therapy.

In patients with suspected bronchiectasis, thin-section images have supplanted bronchography as the best method for demonstrating airway dilatation, wall thickening, and mucous inspissation. Because bronchiectasis is often discovered in patients with hemoptysis, high-resolution CT is an important component of the diagnostic workup in patients with normal or inconclusive chest radiographic findings. The detection of bronchiectasis may also explain chronic cough or recurrent pneumonia not explained by conventional CT imaging or bronchoscopy. The demonstration of multifocal involvement appropriately identifies patients whose disease cannot be cured by surgical resection.

High-resolution CT is frequently added to conventional CT to further characterize focal abnormalities. In patients with diffuse lung disease, a dedicated high-resolution CT examination, consisting of 1- to 2-mm sections every 10 mm, is performed to obtain a representative sample of the lung parenchyma. The current indications for a dedicated high-resolution examination are as follows:

- To investigate signs and symptoms suggestive of diffuse lung disease in patients with normal or nonspecific chest radiographs;
- To investigate cases in which the chest radiographic abnormalities are not in keeping with the clinical presentation;
- To provide an index of disease activity, especially in patients with usual interstitial pneumonia;
- To determine the most appropriate type and site of lung biopsy;
- To diagnose bronchiectasis, and to determine its distribution.

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REFERENCES

Aberle DR: HRCT in acute diffuse lung disease. J Thorac Imaging 1993; 8:200-212

Müller NL, Miller RR: State of the art: Computed tomography of chronic diffuse infiltrative lung disease—Part 1. Am Rev Respir Dis 1990; 142:1206-1215

Padley SP, Adler B, Müller NL: High-resolution computed tomography of the chest: Current indications. J Thorac Imaging 1993; 8:189-199

Swensen SJ, Aughenbaugh GL, Douglas WW, Myers JL: High-resolution CT of the lungs: Findings in various pulmonary diseases. AJR Am J Roentgenol 1992; 158:971-979

Preoperative Staging of Lung Cancer

STAGING OF LUNG CANCER is used primarily in patients with non-small-cell carcinoma. With rare exceptions, small-cell carcinomas, whenever discovered, are considered to have already metastasized and therefore are classified as stage IV.

The staging of non-small-cell lung cancer is based on the tumor-node-metastasis system first promulgated in 1974 and revised in 1986. Information required for staging includes the size and position of the tumor, the involvement of adjacent tissues by the tumor, the extent of regional lymph node involvement, and the presence and location of distant metastases. The stage correlates well with the prognosis, with or without treatment.

Preoperative staging is less accurate than the staging determined from tissue biopsies and actual exploration of the chest, but it provides invaluable assistance in selecting the most appropriate therapy. Preoperative staging not only identifies patients in whom thoracotomy would likely be

futile, but also detects its usefulness in situations in which a patient's condition may have originally seemed hopeless.

The status of a primary tumor in the lungs is most effectively studied by thoracic computed tomography (CT), which establishes the size and position of a tumor with precision. If a tumor is situated immediately adjacent to the chest wall or mediastinum, magnetic resonance imaging may be superior to CT in detecting invasion of these tissues. With centrally placed tumors, bronchoscopy will help determine resectability.

Although many surgeons depend on standard chest roentgenograms for evaluating the hilar and mediastinal nodes, thoracic CT with contrast enhancement has had an increasingly important role in this type of analysis. The usual practice has been to recommend mediastinoscopy if CT indicates that one or more nodes are enlarged and to advise exploratory thoracotomy without mediastinoscopy if the nodes are normal-sized. It has long been recognized that as many as half of the enlarged nodes are benign, and more recently it has been shown that 30% to 40% of nodes already involved with malignant spread appear normal in size. Some have suggested that a false-negative rate of this magnitude for CT would not warrant its routine use for staging nodes.

The new technique of positron-emission tomographic scanning shows promise of providing the highest sensitivity and specificity of all noninvasive methods for staging the hilar and mediastinal nodes and may well become the method of choice in the future. Because such scans include the entire body, they may prove to be the most cost-effective method for detecting widespread extrathoracic metastases.

The choice of techniques for detecting metastases depends largely on clinical clues suggesting focal disease. Techniques used include contrast CT scans or gadolinium-enhanced T1-weighted magnetic resonance images of the brain, bone scans, abdominal CT, and study of presumably malignant pleural effusions by thoracentesis and pleural biopsy. Although there is no clear consensus on using "routine" searches for metastases in the absence of focal signs, it is usual for the standard thoracic CT to be extended to include the liver and adrenal glands. In patients with isolated ipsilateral mediastinal or subcarinal nodal involvement (stage IIIA), routine organ scanning—brain, bone, liver, adrenal glands—is probably advisable because of the increased likelihood of metastasis.

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REFERENCES

Moore EH, Templeton PA: Imaging the advancing frontier of lung cancer operability. Semin Respir Med 1992; 13:293-308

Wahl RL, Quint LE, Greenough RL, et al: Staging of mediastinal non-small cell lung cancer with FDG, PET, CT and fusion images: Preliminary prospective evaluation. Radiology 1994; 191:371-377

Primary Pulmonary Hypertension

IN THE PAST FEW YEARS our understanding of the diagnostic evaluation, prognosis, and treatment of primary pulmonary hypertension has grown. Noninvasive evaluation still includes an initial electrocardiogram and chest radiograph as screening studies. In affected patients, about 90% of chest x-ray films suggest the diagnosis of primary pulmonary hypertension. Doppler ultrasonography, when tricuspid or pulmonic regurgitation is present, can estimate pulmonary artery pressures and has largely supplanted periodic angiography to assess therapy. All patients should also undergo ventilation-perfusion scanning to identify the small subset of patients with chronic thromboembolic disease because recent studies of surgical pulmonary endarterectomy show superb results, with a surgical mortality of 8% to 9%.

Initial catheterization is still warranted both to confirm the diagnosis of primary pulmonary hypertension and to exclude left ventricular dysfunction and valvular and congenital cardiac causes. Pulmonary angiography is only useful in those patients with abnormal ventilation-perfusion scans, to search for surgically accessible, organized, proximal clots. Open-lung biopsies are rarely indicated.

Accrued data from the National Institutes of Health national registry of patients with primary pulmonary hypertension now provide us with clear prognostic indices. A right atrial pressure greater than 20 mm of mercury predicts a median survival of one month, compared with 46 months for a pressure of less than 10 mm of mercury. A pulmonary artery pressure of greater than 85 mm of mercury is associated with a median survival of one year, compared with 48 months for a pressure of less than 55 mm of mercury. Female sex, low cardiac output, and reduced mixed venous saturation also indicate a poor prognosis.

The therapy for primary pulmonary hypertension has evolved. Vasodilator trials, conducted with a Swan-Ganz catheter and arterial pressure monitoring, are useful for assessing patients' tolerance of vasodilators. Recent data showing that as many as 25% of patients with primary pulmonary hypertension respond to high doses of calcium channel blocking agents, particularly nifedipine, have added impetus to these studies. In patients who respond to therapy, pulmonary artery pressures will return to nearly normal, the right ventricular hypertrophy will subside, and they will live much longer.

A newer vasodilator agent, still not commercially available, is epoprostenol (prostaglandin I_2), also called prostacyclin. Given through a central venous catheter by continual infusion, epoprostenol prolongs survival in most patients with primary pulmonary hypertension and is therefore useful for those in whom calcium channel blockers are ineffective. Side effects include headache, flushing, and hypotension. A synthetic analogue of epoprostenol, iloprost, has a longer half-life and holds promise as a possible oral agent.

Nitric oxide gas (endothelium-derived relaxing factor) is also a potent vasodilator, but with a half-life of only a few seconds. Because of this, when given by inhalation, it achieves selective pulmonary vasodilatation. The chief stumbling block has been the absence of a safe and convenient method of delivery in its therapeutic range of about 2 to 40 ppm.